New Radiation Issues for Spacecraft Microelectronics -Commercial Off-The Shelf (COTS)

Chuck Barnes

Radiation Testing and Failure Analysis Group

Electronic Parts Engineering Office (507)
charles.e.barnes@jpl.nasa.gov

(818) 354-4467

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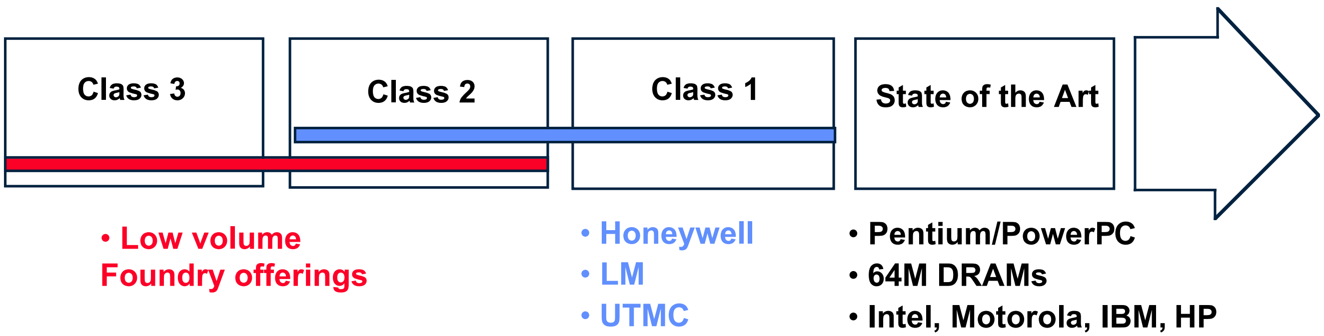
Commercial-off-the-shelf (COTS) parts in space

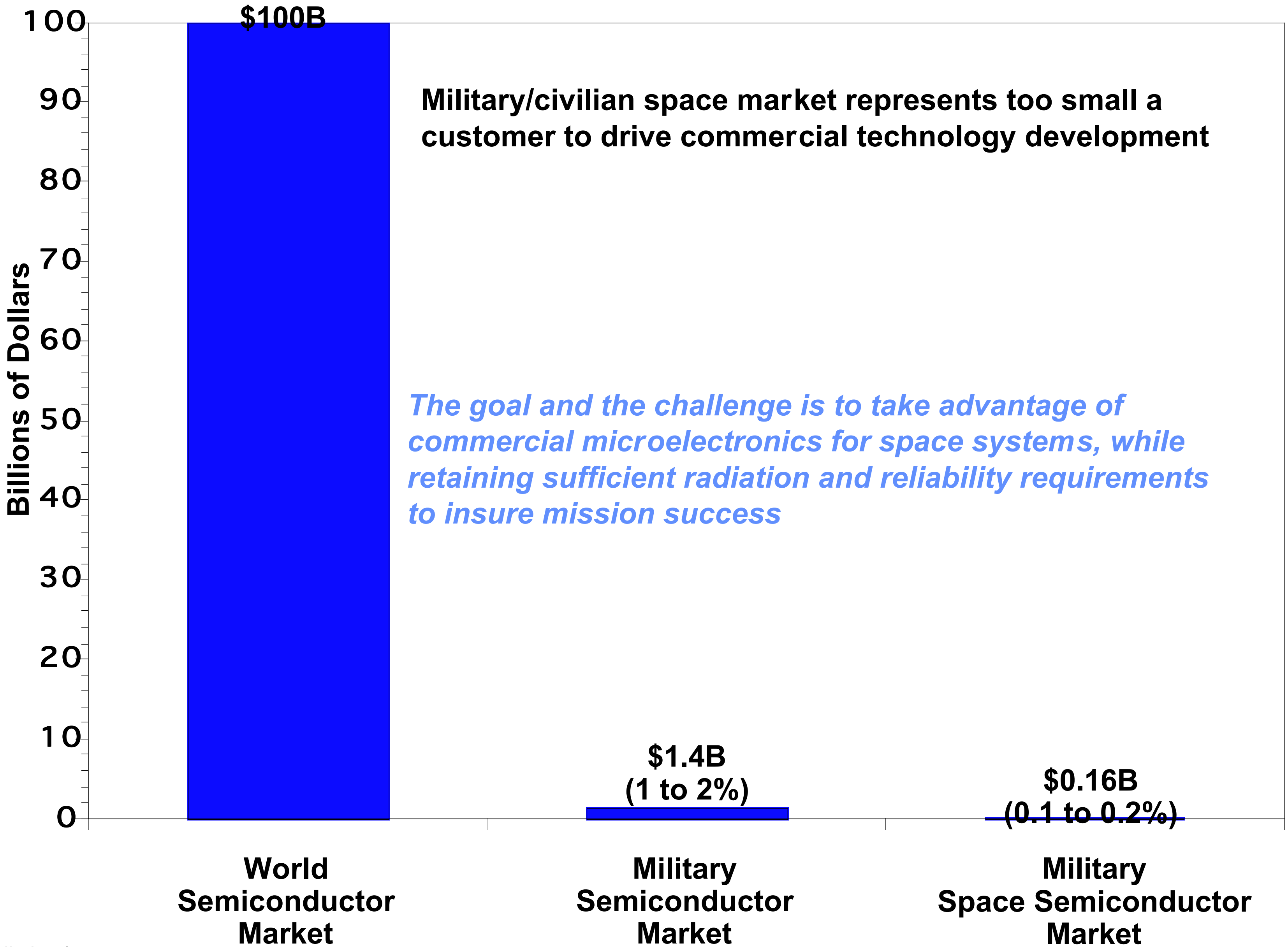
Impetus for COTS Use in Space

- Access to high performance, state-of-the-art microelectronics - difficult to achieve with small, custom parts purchases



- Large, standardized software base
- Lower cost
  - Although upscreening can raise cost substantially
  - Parts are small fraction of total satellite/spacecraft cost (5 to 10%), but this cost will be relatively higher in future
- Decreased availability of parts off rad-hard processing lines
- Greater government reliance on industry standards and specifications for part procurement (Perry Directive)
- For NASA, new paradigm of “Better, Faster, Cheaper” allows for risk management rather than complete elimination of risk, and requires quick, inexpensive procurements

World Semiconductor Device/Circuit Business



Problems with Use of COTS in Space

- **Small customers (space) cannot drive development, specifications or requirements**
- **Life cycle costs can actually be higher for COTS-intensive satellite due to added testing, part and system failure, system re-work, added cost of shielding**
- **Reliability data on COTS is often unknown or unavailable to small customer**
- **Commercial competitiveness to reduce cost, improve performance can jeopardize availability of specific parts required in future systems**
- **Space applications do not usually allow for repair or replacement**
- **Plastic encapsulated microcircuits (PEMs) are very popular and more reliable than previously, but can still pose problems for space use**
  - Handling and assembly problems
  - Encapsulants vary in composition and properties
  - Moisture absorption - “popcorning”
  - Limited temperature ranges
  - Differences in thermal expansion coefficients are a problem with thermal cycling
- ***Radiation is a big problem***

Radiation Complicates COTS Usage

- **Reliability and RHA often unknown**
- **Radiation is unique**
  - Can't leverage off other high rel users like automotive
- **TID response depends on process**
  - "Positive" changes can reduce radiation tolerance
  - NASA technical penetration often difficult
- **SEE depends on circuit design and dimensions**
  - Commercial vendor can change these without notice
- **No good way of predicting radiation response without testing**
  - *IRONY* – Process knowledge, testability and penetration are where you don't need them – rad hard process lines
- **Packaging can make RHA hard to establish**
  - Flip chip bonding
  - SEE hard to do on plastics
  - Multichip modules (MCMs) hard to test

Approaches to Using COTS in space

- **Work with commercial suppliers to obtain reliability and radiation data**
- **Encourage data and information sharing among commercial parts vendors, users and the government**
- **Evaluate commercial process lines, when possible, to determine SPC, workmanship quality, reliability and radiation hardness**
  - Similar to QML audits performed by DESC
  - Must include assessment of quality of data
- **Re-examine screening and failure analysis requirements and techniques to determine if they are really needed and their relevance to COTS usage**
- **Develop process line “tweaks” that will enhance reliability and/or radiation tolerance but are minor enough to be implemented by commercial parts vendors**
- **Evaluate design techniques for introducing radiation hardness and reliability through design changes**
  - Single event effects are amenable to this, but not total dose effects
  - Particularly important for SEL - that’s all many users care about
- **Maintain a vigorous, healthy test activity to provide continuous evaluation of radiation tolerance and reliability**
  - As noted earlier, rad tolerance can change without notice
- **Through working groups and consortia, evaluate standards and specifications and establish new standards for procurement**

JPL RHA Activities in Support of Advanced COTS Usage

- **Radiation analysis and testing of COTS parts**
  - Support to NASA flight projects
  - Cheaper, easier test methodologies
- **Radiation risk mitigation techniques**
  - Latchup mitigation
    - Circuit solutions
    - Neutron irradiation
  - RadPak, shielding
  - Mitigation of hard errors, dielectric rupture
  - Software mitigation techniques
- **Evaluation, research**
  - Advanced COTS technologies
    - FPGAs, DRAMs, highly scaled devices, MCMs, MEMS, photonics, III-V-based technologies
  - New radiation phenomena
    - Enhanced low dose rate effects
    - FPGA anti-fuse rupture and connection
- **Dissemination of radiation data**
  - RADATA data bank
  - URL: http://radnet.jpl.nasa.gov

COTS Summary

- **It is inevitable that space flight systems will use COTS to a greater degree in the future; already taking place to a limited extent**
- **There are still many space applications where it would be very difficult to use large percentages of COTS parts**
- **Life cycle costs can actually be less for radiation hardened parts than for COTS**
- **Watch out for hybrids - can contain vulnerable parts**
- **No single, elegant solution exists for RHA problems associated with use of advanced commercial parts in space**
  - Mission performance and radiation environment requirements can vary drastically
  - A variety of solutions can be used for any given mission
    - Establish RHA with rad testing
    - Disseminate rad data to designers so they can use it early in project cycle
    - Use various shielding techniques
    - Use software and hardware mitigation methods
    - Use modified commercial designs that are more rad tolerant
    - Go to captive lines for rad hard product
  - *Implementation of solutions is more difficult than identifying solutions*
    - Projects have no funds for RHA early in cycle